The Effects of Receive Field Contrast on Motion-Corrected EPI Time Series: A Simulation of a 32 Channel Receive Array

Daniel J Sheltraw[1] and Ben Inglis[1]
[1]*Henry H. Wheeler Jr. Brain Imaging Center, University of California Berkeley, Berkeley, CA, United States*

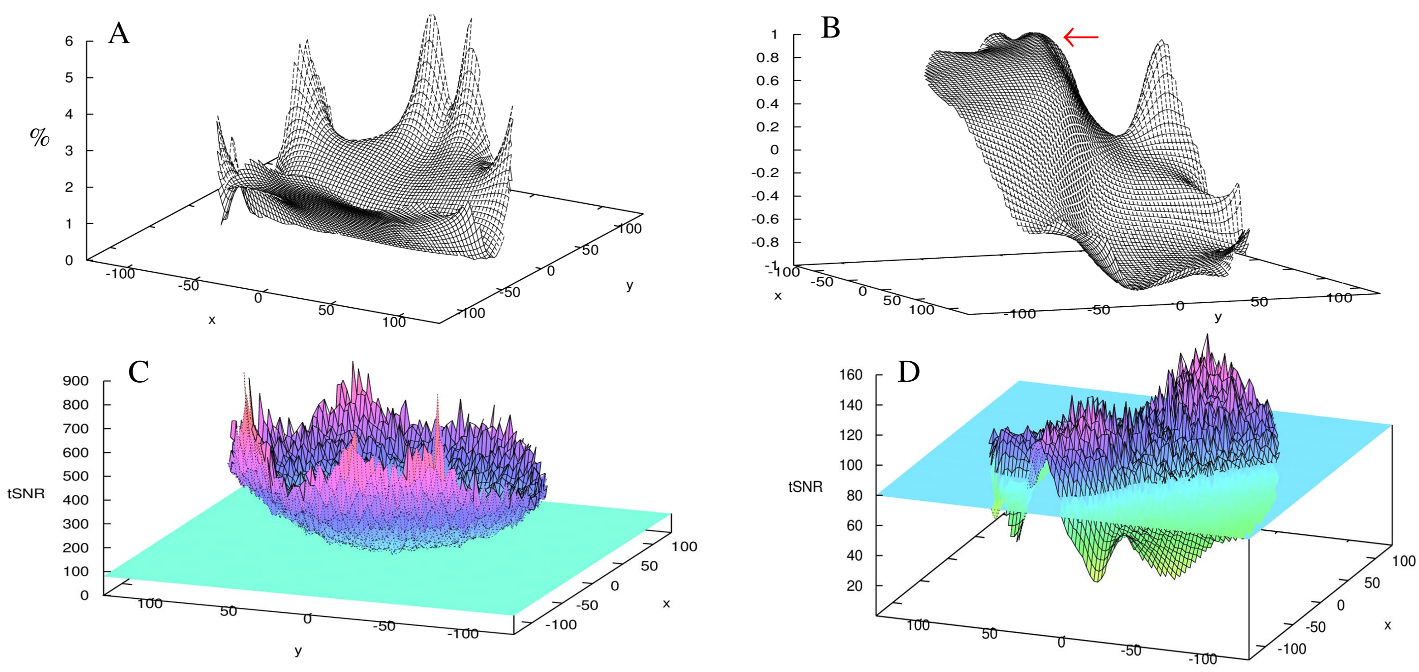
Purpose: Receive coils impart an image contrast that is spatially fixed relative to the scanner. If motion correction is applied to EPI time series then the receive field contrast will effectively move relative to the subject and produce temporal modulations in the image amplitude. These modulations can be misinterpreted as BOLD signal changes and may be especially problematic for fMRI connectivity studies [1]. We present a simulation of this effect, which we term the Receive Field Contrast - Motion Correction (RFC-MoCo) effect, to better understand its severity. The simulations examine the effect for a 32-channel head array and assume perfect motion correction. We study: (1) Effect size; (2) Spatial-temporal correlations; and (3) Temporal SNR (tSNR) of an image time series.

Methods: The geometry of each coil element of the array is approximated with 8 line segments. The receive field due to a given coil element may then be calculated from the receive field due to each of its line segments – for which an exact mathematical form is obtained by a Biot-Savart Law integration. Composite images of a simulated homogeneous phantom are next reconstructed according to the usual sum-of-squares method for receive arrays. Over a 95 mm radius region of interest centered within an axial slice at z=125 mm we compute: (1) Percent difference map (noiseless) due to 1 mm in-plane translational motion, and (2) tSNR maps (with added noise) and temporal correlation maps (noiseless) due to a realistic time series of rigid body motion parameters obtained from an fMRI experiment. Where applicable, Gaussian noise added to the simulated data gives a typical tSNR of 80 at the center of a motionless head.

Results: Figure A shows the percent difference map where for many points the RFC-MoCo effect is greater than the typical BOLD contrast changes at 3T. Figure B shows the temporal correlation map over the axial slice when the sample is assumed to move according to a realistic time series of 70 repetitions. The correlation is between a seed point at x, y, z = 78, 0, 125 mm (red arrow) and all points within the region of interest. (Correlations are invariant to the rms translation in these noiseless simulations.) Figures C and D show the percent degradation of tSNR for 1.0 mm rms translational motion (Fig D) compared to no motion (Fig C), using the same 70 volume time series as for Figure B. The plane in Figures C and D indicates the level tSNR = 80.

Discussion: Signal changes arising from the RFC-MoCo effect are likely to compete with BOLD signal changes in the presence of typical motion. Consequently, we find that this effect may lead to spurious temporal correlations across image space, and that tSNR may be degraded with increasing motion, even when motion correction is assumed to be perfect. Furthermore, since significant signal change can occur due to motion on a sub-pixel spatial scale the correction of the RFC-MoCo effect by means of data acquired on a pixel scale (eg. prescan normalization [2]) may be insufficient. New methods to ameliorate receive field contrast effects are urgently needed in fMRI.

References:[1] Power JD et al, NeuroImage 59, 2142-2154 (2011). [2] Hartwig A et al, Proc. Intl. Soc. Mag. Reson. Med., 12, 3628.



Figures A: Percent difference map. B: Correlation map. TSNR map for no motion (C) and 1 mm rms realistic motion (D).